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GLIDE DISCHARGES ON INSULATORS IN TRANSFORMER OIL DUE TO VOLTAG--ETC(U)
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GLIDE DISCHARGES ON INSULATORS IN TRANSFORMER OIL DUE TO VOLTAGE PULSES

by

W. Hauschild

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By: W. Hauschild

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Information from the High Voltage Laboratory, Electrical Department, Technical University Dresden

Glide Discharges on Insulators in Transformer Oil due to Voltage Pulses[1]

By W. Hauschild[2]

With 17 Illustrations (Received 1/19/71)

Summary:

Glide discharges on insulators in transformer oil cause erosive destruction of the solid insulating material, and may cause flashover from the leader discharge, which occurs at a low specific flashover voltage of appr. 10 kV/cm. The leader initiating voltage is reduced hyperbolically with increased specific surface capacitance of the glide configuration. If subjected to voltage pulses - contrary to the behavior within free oil space - several leader discharges occur, sequentially. They are, every time, associated with current group impulses, starting at the glide pole and partially utilizing the tracks of previously occurred leaders. At very high specific surface capacitances, the current density, and thereby the conductivity, increases in the leader tracks on account of the large capacitive currents. Consequently, the longitu-

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[1]The investigations were carried out on behalf and with the support of the VEB Transformatoren- and Roentgenwerk Dresden. The author expresses his thanks to Prof.Dr.-Ing.F.Obenaus and Prof.Dr.-Ing.Habil W.Mosch for valuable suggestions.

[2]Dr.-Ing.Wolfgang Hauschild, DDR-806 Dresden, Nordstrasse 34.

dinal gradient in the tracks of such "reversing leaders" can diminish below the value of 10 kV/cm. The transition from leader to reversing leader occurs at peak voltages which will be as lower, as shorter the rise time of the voltage pulse will be.

1. Introduction

Glide discharges occur at boundaries between a gaseous or liquid, respectively, and a solid insulating material of higher electric strength, when changes occur in the voltage u and/or the capacitance C of the insulating configuration in such a way, that large capacitive currents i_c are able to flow in a partial discharge track:

$$i_c = C \frac{du}{dt} + u \frac{dC}{dt} \tag{1}$$

The boundary in a glide configuration runs usually oblique in the space charge free field (oblique boundary). A large capacitance (specific surface capacitance) exists between the oblique boundary and the counter electrode relative to the surface element, which greatly affects the voltage distribution and, thereby, the glide discharge mechanism (refer to Obenaus and others [1]). The high currents which flow during glide discharges [Eq.(1)] firstly cause erosive destruction of the solid insulating material already at partial discharges and, secondly, generate a flashover mechanism which results in low specific flashover voltages. Glide discharges on insulators and within insulations are therefore especially dangerous and should be avoided at all required loads. This principle was recognized early and caused numerous investigations of glide discharges. The discovery of essential relations between the initiation and growth advance of glide discharges in air is due to Toepler [2], in whose honor planar glide configurations are designated as "Toepler

glide configuration" in distinction to those of the lead-through principle.

In a glide configuration in air, during flashover, at first streamers emerge from the glide pole [2]. However, at a certain range of the streamers, which depends on the specific surface capacitance (and corresponds to "glide discharge free strike range"), the discharge changes into a thermo-ionized leader ("glide discharge" [2]), because the current density in front of the glide pole surpasses a critical value due to capacitive currents [Eq.(1)]. The flashover voltage is therefore determined by the low longitudinal gradient of the leaders ($\leq$ 1.5 kV/cm). Technical insulating configurations are dimensioned such that the flashover range remains smaller than the "glide discharge free strike range". Their dependency from the specific surface capacitance and the leader initiation voltage ("glide initiation voltage") as well, can be calculated by means of empirical formulas for configurations in air [1]. In the literature, it has been attempted at times, to apply the empirical formulas derived for glide configurations in air to glide configurations under oil also [3].This leads, however, in practice to unsatisfactory results because in the flashover process in oil , as compared with air, the streamer discharge is absent [4]. Because the flashover of highly inhomogeneous oil configurations occurs already at centimeter strike ranges out of the leader discharge [4], the flashover voltage of glide configurations under oil diminishes less as with corresponding configurations in air, in comparison with the flashover voltage of free oil insulating sections. Glide discharges in oil destroy the solid insulating material by erosion at a fast rate [5],so that they must be avoided in technical oil insulations at operating voltages.However, at pulse test voltages or at over-voltages, glide discharges are usually tolerated in oil

insulations.It is therefore important to know the relations between the initiation and growth advance of the thermo-ionized leader in glide configurations under oil for switched voltage potential.

During his fundamental investigations, Staack [6]found by means of the photogram method ,that the strike range of glide discharges under oil increases with the rise time of the applied voltage wave form. However, data for the discharge current and the space/time-related discharge process are still missing. It has,further, not yet been tried, to incorporate glide discharges into the general systematics of oil flashovers. With the presented investigation, it is intended to make a contribution towards supplementation of the concepts of glide discharges under oil, and to identify likely characteristics at pulse voltages.

2. Experimental Technique

All experiments were carried out with Toepler glide configurations(Point-to-plate;Fig.1) with a pointed electrode as glide pole under dry (water content:10-30ppm) air saturated transformer oil, using positive and negative pulse voltages (rise times: 1-500μs; fall times: 50,3500 and 5000μs). For the measurement of initial voltage, discharge current, impulse charges and strike range of glide discharges, the grounded point-electrode consisted of a measurement sonde (steel needle with point radius of 0.02 mm) with conical shield (aperture angle 15^0), in order to reduce the capacitance towards the high voltage electrode (plate). As solid insulating material were employed hard paper (ε_r = 6.5) and hard fabric (ε_r = 8.8). Both materials possess an almost equal surface structure (average roughness: 4μm). The glide configuration is further identified by its specific surface capacitance.

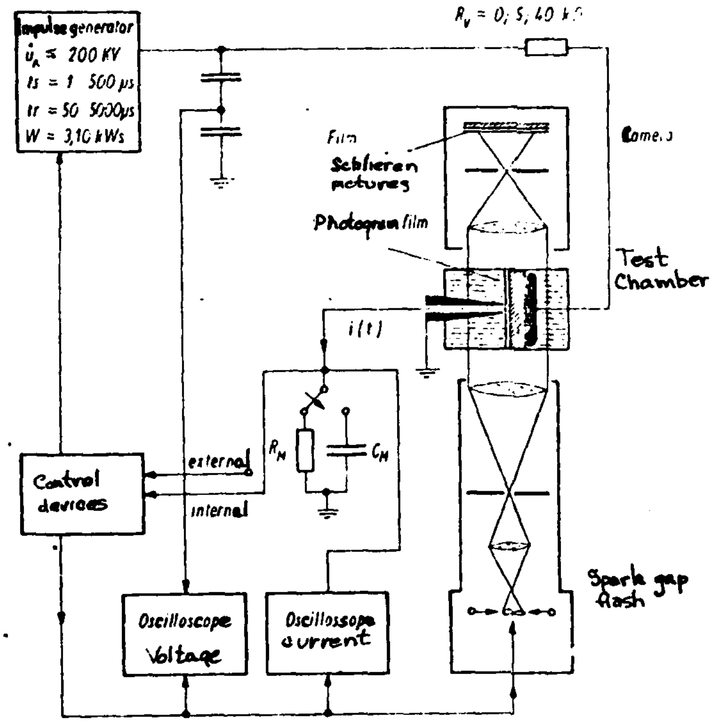


Figure 1.
Test Schematic
with Schlieren
Camera

The selected experimental technique permitted to observe the discharge processes in the space/time-frame. For measurement of the discharge current i, the sonde of the point electrode was connected to ground via a resistance R_M (Fig.1). The voltage along R_M was recorded by oscillograph, with the coaxial instrument cable terminated in its own characteristic impedance. The cut-off frequency for the entire measurement circuit was 30 MHz [4]. With the measurement sonde connected to ground via capacitor C_M and an impedance transformer preventing discharge of the capacitor, the oscilloscope would record the current integral which is equal to the pulse charge [7]. In synchronism with the measurement of electrical parameters, discharge photographs were taken. The discharge tracks, extending directly along the boundary surface, directly expose a planar film positioned there, following the classical method of photogrammetry. The fine structure of the discharge

pictures on the photograms were analyzed under a microscope. Discharge tracks within the free oil space were recorded by means of the Schlieren process [8]. The Schlieren process is based on the formation of parallel light beams from the light of a triggered spark discharge (duration 3μs [4]), so that the light beam (Fig. 1) penetrates the test chamber at the instant of discharge. The discharge tracks are projected as shadows onto a photographic film by a second lense system. The pulse voltage generator is triggered by means of a control instrument (Fig.1), while triggering of the oscilloscope and light flash can be controlled optionally, either externally by the control instrument or by the discharge current itself.

In order to measure the flashover voltage, the voltage was increased in even increments up to the flashover point. At each step, a load was applied. From 20 such test series, the 50%-flashover voltage was computed statistically and established with safe confidence (probability of error 5%).

3. Discharge Processes

The discharge processes will be treated in the same sequence in which they occur, when the voltage potential with a fixed, preselected rise time, is increased from zero to the flashover value.

3.1 Continuous Discharge

After the transition from non self-sufficient to self-sufficient discharge, for which field strengths in the order of 750 kV/cm are required [4], pulse-free currents flow in the microampere range. The discharge form with these characteristics shall be designated as "continuous discharge". The continuous discharge creates space charges with low mobility in front of the electrode with the smaller radius of curvature, making the field uniform. These space charges prevent the

flashover process in free, slightly inhomogeneous, oil sections [9], but in glide configurations they only effect that the subsequent discharge form with pulse characteristic - the leader - begins to occur at somewhat higher voltage potentials.

3.2 Leader

Leader are the discharges which determine the flashover process. Leader intiating voltage and leader longitudinal gradient are hardly affected by polarity.The discharge characteristic and electrical discharge parameters are therefore treated together for both cases of positive and negative glide poles in the following text.

Whenever the current graph shows the occurrence of pulses, the photographs show discrete discharge tracks of appr. 1 mm lengths. Both phenomena are characteristic for leader initiation, during which an ionized gas/vapor-phase exists in the oil [8]. The leader intiating potential as well as flashover potential are determined as 50%-value through step increments of the potential (refer sect.2). Since the leader initiating potential $u_{\Delta L}$ is a function of the peak field strength at the glide pole, it should diminish with increasing specific surface capacitance c (Fig.2) in accordance with the hyperbolical equation, which, in its general form is also valid for glide configurations in air [1], as follows:

$$\hat{u}_{\Delta L}/kV = K_1 \, c^{-k_2} \, / F \, cm^{-2} \qquad (2)$$

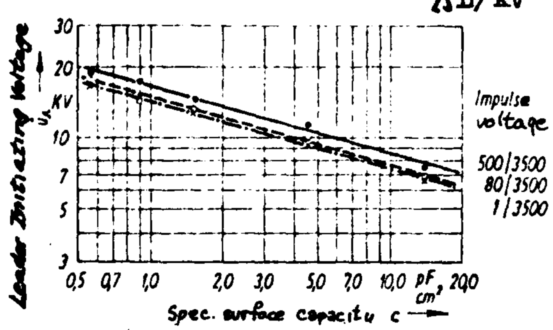


Figure 2.
Leader Initiating Potential versus Specific Surface Capacitance

Thereby is at first assumed that the effect of the continuous discharge remains negligeable. An experimental verification of the relations expressed by formula (2) with pulse voltages 500/3500 verified the stipulated theories (Fig.2) and resulted into the following values for the empirical constants: $K_1 \approx 9.03 \cdot 10^{-4}$, $K_2 \approx 0.30$ (comparative values for air are: $K_1 \approx 1.355 \cdot 10^{-4}$, $K_2 \approx 0.44$ [1]). Orientation measurements with steeper pulse voltages (80/3500; 1/3500) showed that the leader initiation voltage - and thereby the factor K_1 - diminishes with decreasing rise time, slightly (Fig.2). It is likely that with shorter rise times the effect of the space charges originating from the continuous discharge is being diminished [9],but the relation described by formula (2) is basically valid. This means that without doubt the space charge distribution adheres to the space charge free basic field. Determining for the discharge limit voltages is therefore the specific surface capacitance. Within the investigated range of specific surface capacities (0.5 - 20 pF/cm^2) however the discharge processes perform completely similar -with the exception of limit voltages - so that no further differentiation will be made with regard to specific surface capacities.

3.2.1 Discharge Current

While normally in free oil spaces during pulse voltage loading only one current group pulse is registered [4],several such group pulses occur in glide configurations (Figs. 3 and 4). Since each of these group pulses identifies the occurrence of a leader discharge, the time instant of leader initiation can be obtained from the current or charge oscillographs. With increasing peak value of the pulse voltage (which means also with faster rise time) , the number of registered group pulses increases while the start time of the n-th current pulse diminishes (Fig.5). This reduction is so large that for

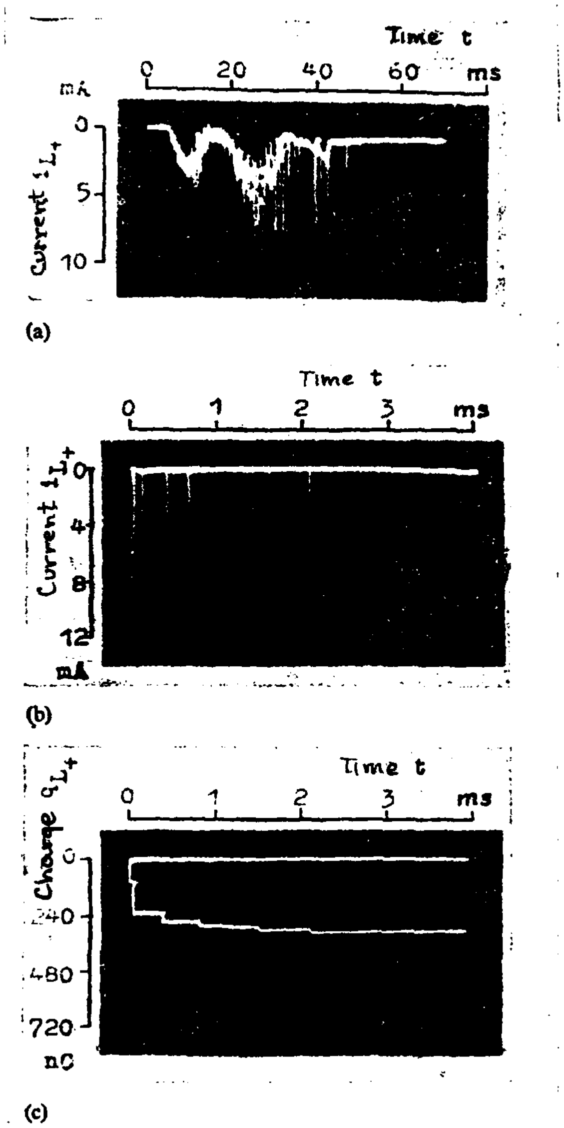


Figure 3. Discharge Current and Pulse Charge
for positive glide pole
(Voltage 50/5000; $\hat{u}_{\Lambda}$ = 90 kV; c = 0.9pF/cm^2)

a) discharge current around leading edge (read micro-seconds instead of milliseconds)

b) discharge current (over-all view)

c) pulse charge (overall view)

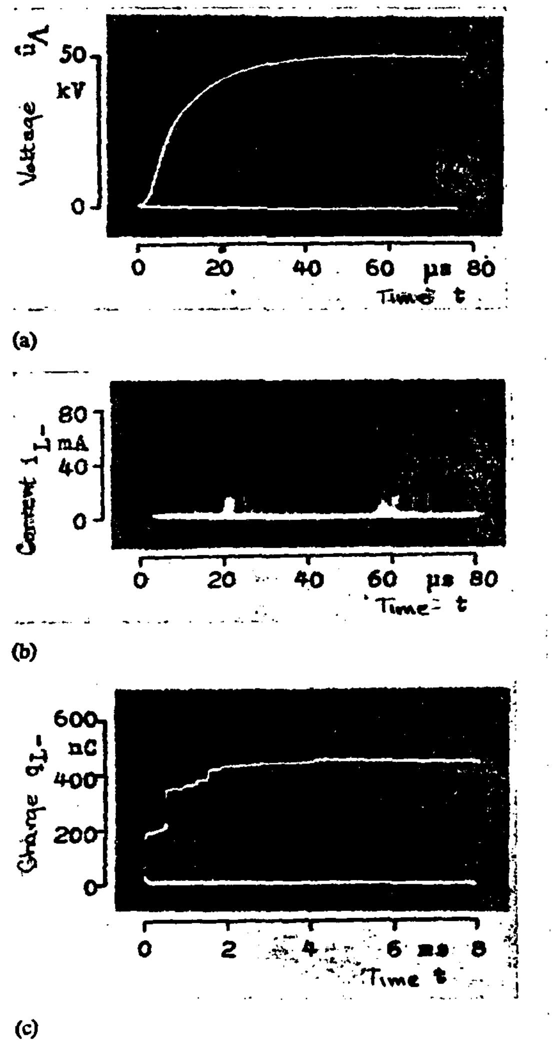


Figure 4. Terminal voltage, discharge current and pulse charge for negative glide pole ($c = 0.9$ pF/cm^2)

a) Leading edge of terminal voltage (50/5000)

b) Discharge current around leading edge

e) pulse charge (over-all oscillogram)

leaders which start at the leading edge of the voltage pulse the initiation voltage does not only remain constant with increased pulse steepness but even diminishes (refer 3.1). For leaders with the same serial number, the initiation time with positive glide pole occurs later than with negative glide pole (Fig.5). As with free oil spaces[4], field emission occurring at the negative glide pole produces electrons which facilitate leader initiation which relies on the formation of a gas-vapor phase.

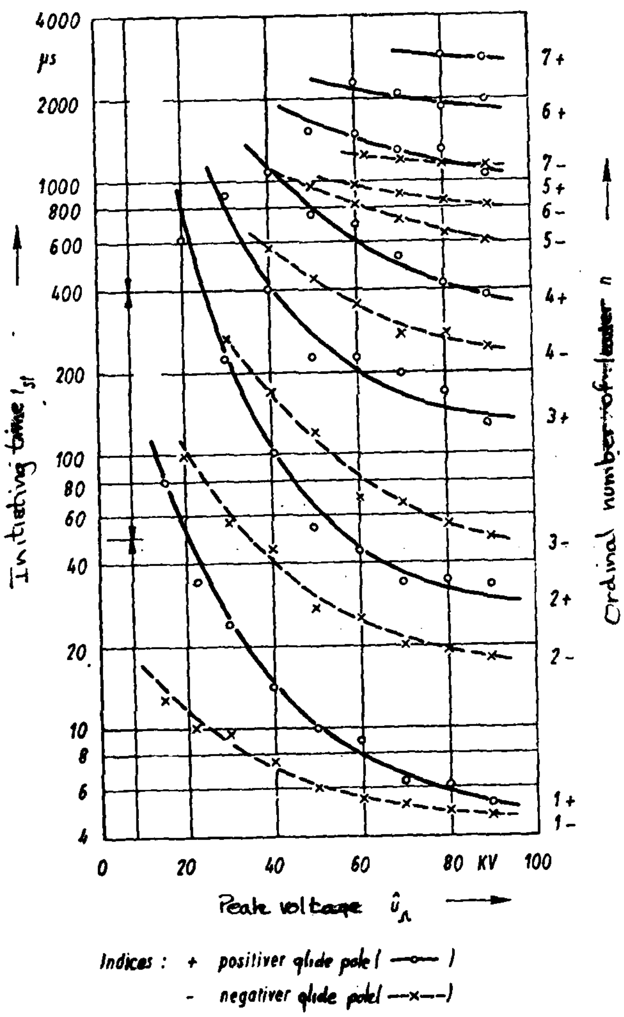


Figure 5
Leader Initiation Time vs Peak Voltage
($c=0.9pF/cm^2$; 50/5000)

The discharge current connected with a positive leader consists, as in free oil space, of pulses which superimpose each other to form a pulse group (Fig.3a). The duration of the group pulse can however amount up to 50 μs. It is thereby considerably longer than in comparable free oil space. The peak values of the group pulses diminish as a rule with the serial number of the leader (Fig.3b) as does the pulse charge (Fig. 3c ; the step height being proportional to the pulse charge).

Within negative leader current, pulse groups are formed from spaced pulses as in free oil space (Fig.4b). As with positive glide poles, the pulse charge of the leaders diminishes with increased serial number (Fig.4c). The maximum peak current[1] of negative leaders is considerably larger and and increases faster with the voltage peak value as a positive leader (Fig.6). However, the total charge of positive leaders during voltage pulse loading is considerably higher than the total negative charge (Fig.7).

A physical explanation of the plotted characteristics of the discharge current shall be attempted in the following, together with an analysis of the discharge configurations.

3.2.2 Discharge Configurations

The positive glide discharge configuration is made up of thread-like leaders with few branches which surround the glide pole about concentrically (Fig.8). With increased voltage (Figs. 8a to 8d) not only the range of these leaders but also their number and number of branches increase. With each new

[1] During every voltage loading the maximum peak current was computed from n group pulses. In figures 6 - and figure 7 for the total charge - the average values and mean square deviations for 50 measurement values were plotted.

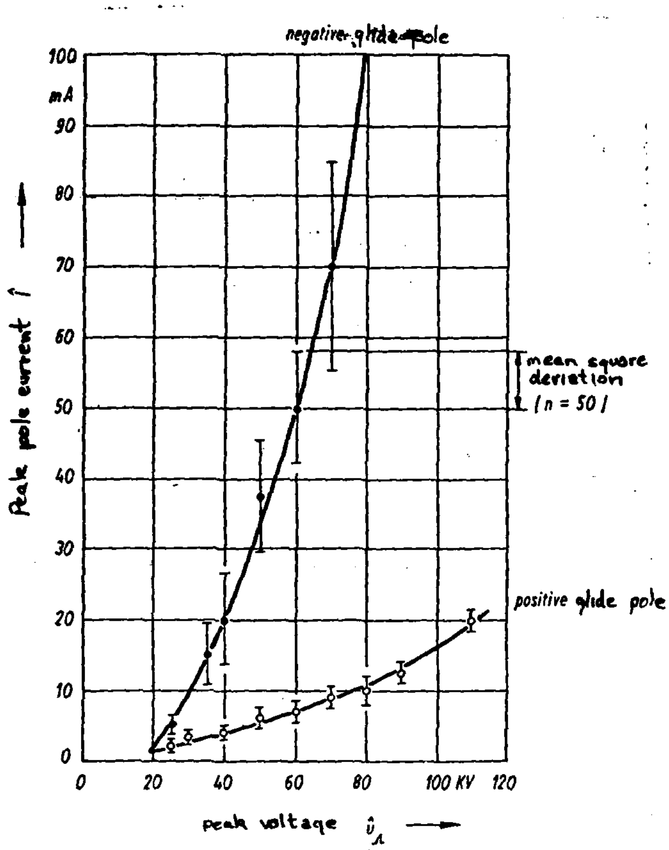


Figure 6
Peak Pulse Current for positive and negative glide pole
($c=0.9pF/cm^2$; 50/5000)

current group pulse a leader process originates from the glide pole.

In order to explain the discharge configuration,the following model concept is used: Every leader constructs a discharge track which consists of a continuous gas-vapor tube from the leader head to the glide pole and contains at first an equal number of positive and negative charge carriers.Since these are almost equally distributed, the track appears to the outside as quasi neutral. When the growth advance of the leader ceases, the charge carriers with a polarity opposite to the glide pole flow off towards it. At the boundary plane,the charge carrier with the polarity of the glide pole

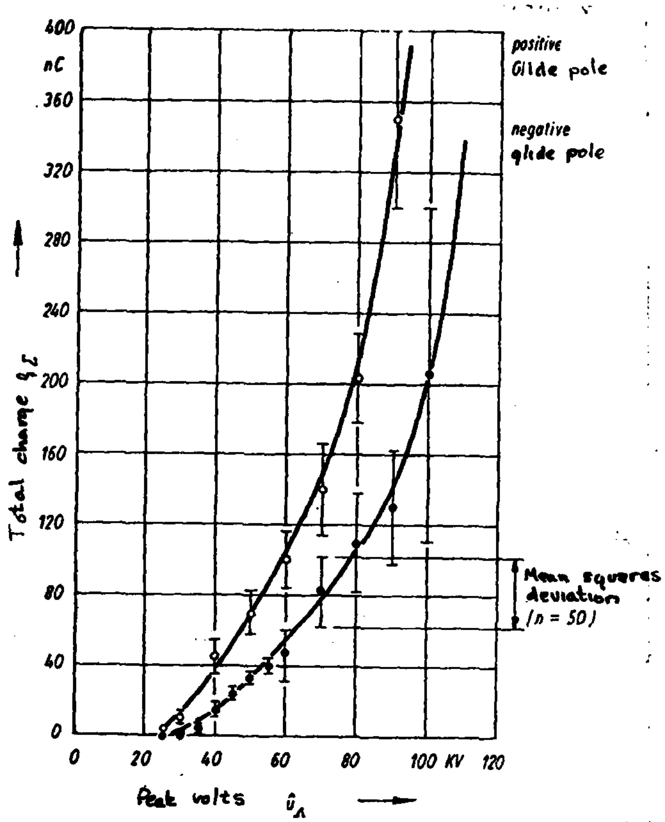
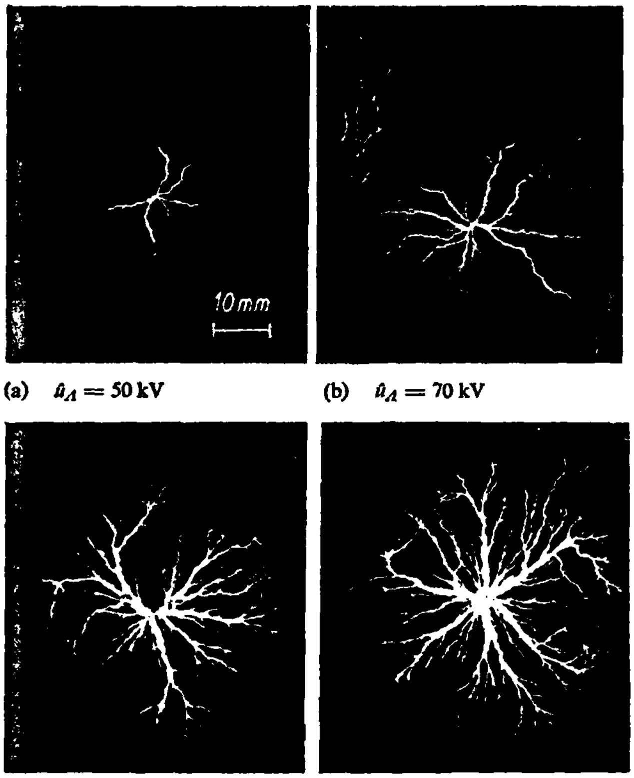


Figure 7
Total charge
for positive and
negative glide po-
le
($c=0.9pF/cm^2$;
50/5000)

remain. After a certain time, which is of the order of 100 μs, gas and vapor in oil dissolve, and the trace of the discharge track on the boundary plane acts as a unipolar surface charge.

Subsequent leaders use the pre-ionized tracks of the precessor if they still maintain the quasi neutral condition. In this case, the peak current and the pulse charge of the subsequent leader increases compared with the precessor.Frequently this phenomenon appears for the second leader during voltage loading (Figs.3b and 3c).

If the time between the two examined group pulses is so large that the unipolar surface charge is already effective, the field strength in the neighborhood of these charges is reduced compared with the charge free case. In this case the



(a) $\hat{u}_A = 50\,\mathrm{kV}$ (b) $\hat{u}_A = 70\,\mathrm{kV}$

(c) $\hat{u}_A = 90\,\mathrm{kV}$ (d) $\hat{u}_A = 110\,\mathrm{kV}$

Figure 8
Discharge Configurations for positive glide pole ($c = 0.9$ pF/cm^2; 50/5000)

subsequent leaders form completely new leader tracks which criss-cross with the traces of previous leaders (Fig. 8d). In such cases of cross overs, the positive leaders lift off a few millimeters from the boundary (Fig. 9a), most likely because near the leader head the field strength component in the direction of the surface charge is smaller as the one in the direction away from the surface. If the leader track is not any more quasi neutral, peak current and pulse charge of a subsequent leader is decreased compared with the previous. This phenomenon usually appears for leaders with a serial number $n > 2$ (Fig.3b and 3c).

If the insulation material oil is modified by the leader

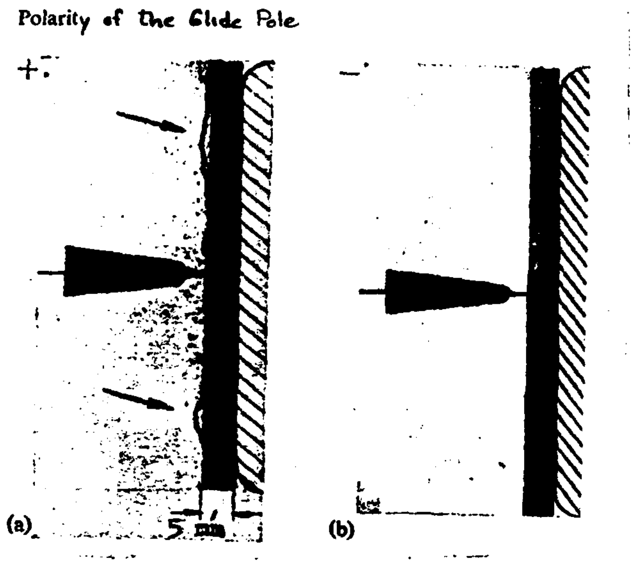


Figure 9. Leader tracks along the boundary for (a) positive and (b) negative glide pole (Schlieren photo)

process into an ionized gas-vapor tube - either by forming of a new leader or by continuation of an existing leader - very high field strengths E_{krit} are required in the order of 3000 kV/cm [4]. Such high field strengths are obtained by all means on the leader tracks, since with a median track diameter of appr. 0.05 mm diameters of less than 0.01 mm have been measured at the pointed track ends (Fig.10 marked "L"). The growth of the glide discharge configuration ceases when the field strength decreases on account of the continuously increasing spacial expansion of the glide configuration, accompanied by voltage drop in the track and the mutual interaction of individual leader tracks below the value of E_{krit}.

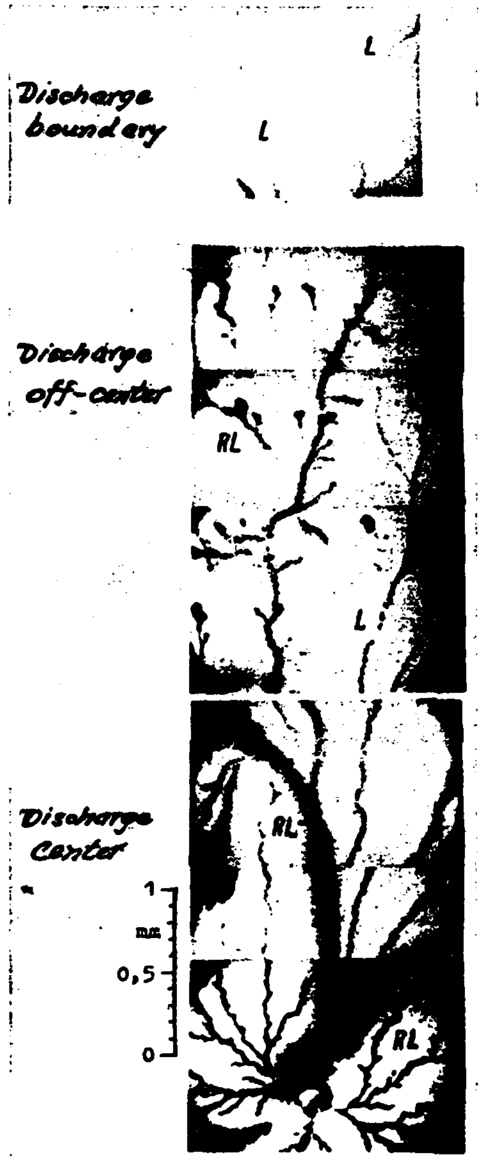
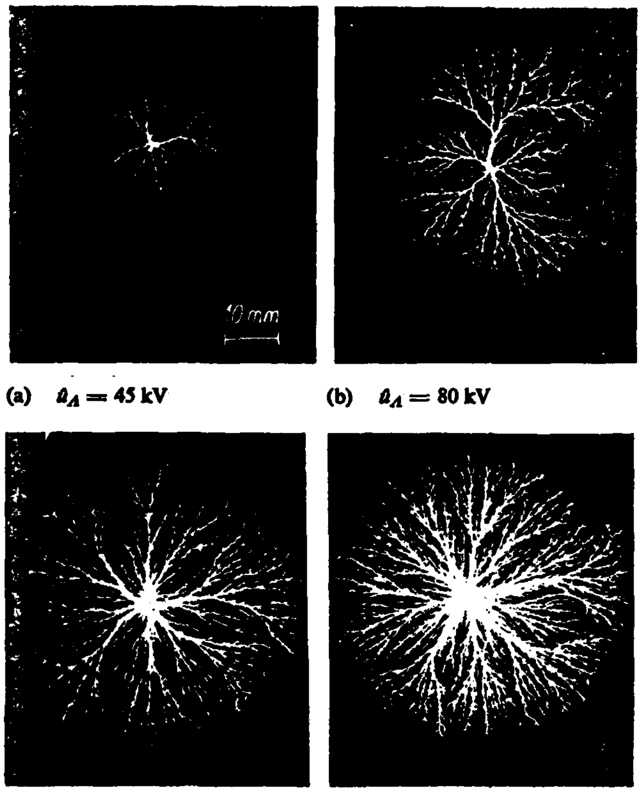


Figure 10. Fine structure of Leader (L) and Reversing Leader (RL) for positive glide pole ($\hat{u}_{\Lambda}$ = 25 kV; 1/3500; c = 8.0 pF/cm^2)



(a) $\hat{u}_A = 45$ kV (b) $\hat{u}_A = 80$ kV

(c) $\hat{u}_A = 125$ kV (d) $\hat{u}_A = 140$ kV

Figure 11
Discharge Configuration for negative glide pole ($c=0.9 pF/cm^2$; 50/5000)

In contrast to the positive, the negative glide discharge configuration is formed by leaders, which possess besides numerous ramifications very many fine branches (Fig.11). The diameters of newly formed leader tracks lie between 0.03 and 0.1 mm, and the tracks are obtuse at their ends (Fig.12).With increased voltage (Fig 11a to 11d) , besides the range of the leader,particularly their number increases within the glide discharge configuration. Moreover, a striking radial symmetrie of the configuration comes into existence. In contrast to positive leaders, negative leaders do not criss-cross another and do not lift off the boundary plane (Fig.9b). It can be assumed that the quasi neutral condition is maintained longer

in the negative leader tracks than in the positive, because the positive ions in the track drift much slower to the negative glide pole than the electrons to a positive glide pole. At negative glide discharge, the leader with higher serial number use principally tracks of previous leaders which are still reproduced by charge carriers of both polarities. Subsequent leaders elongate these tracks and form new ramifications and branches.

During the spread of the thermo-ionized - and therefore conductive - leader, the entire glide discharge acts like a planar electrode [10].The negative leader,as well as the positive,stop on account of the field strength drop at the leader head below the critical value.

3.3 Reversing Leader

It has just been described that subsequent leaders use the tracks of preceding leaders for both positive as well as negative glide poles.In such frequently used tracks, the number of charge carriers and the diameter of the gas-vapor phase increase. These tracks appear particularly thick on photograms (Figs 8c and 8d, 11c and 11d). In current oscillograms, the duration of group pulses increases up to an order of 100 μs (Fig.13). In these long group pulses are,also for positive glide pole , individual pulses of very high amplitude (up to 100 mA) incorporated. Particularly in the center of the positive glide discharge configuration, numerous ramifications and leafy fine branchings appear (Fig.14), which remind of the negative configuration, while around the boundary the usual positive leaders exist. Such leafy branchings are also shown on the enlarged photograms (Fig.10).

Similar phenomena can be observed in free oil space sections, when a leader has grown from its originating electrode

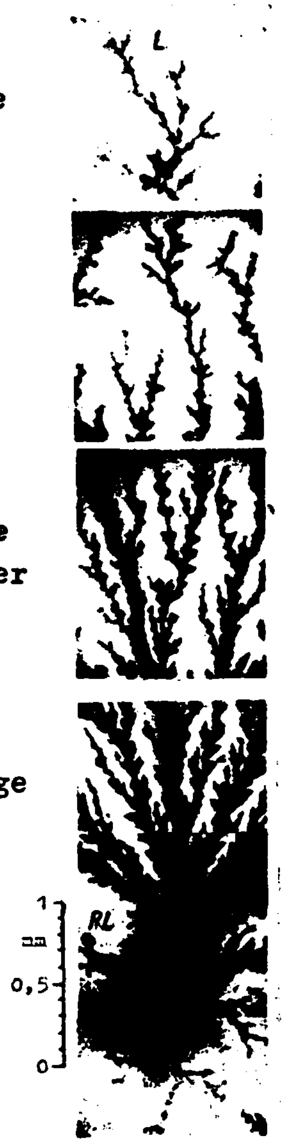


Figure 12
Fine Structure of Leader (L) and Reversing Leader (RL) for negative glide pole
($\hat{u}_{\Lambda}$ = 25 kV; 1/3500; c = 8.0 pF/cm^2)

to the counter electrode. In his track, a "reversing leader" returns to the originating electrode, which shows the characteristics of a leader with the opposite polarity [4]. The same mechanism applies to the phenomena described in connection with glide discharges. A discharge uses the track of a still conductive leader and increases its current density conside-

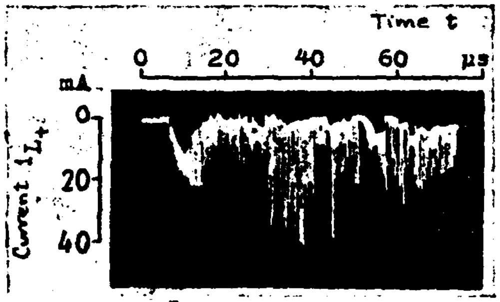
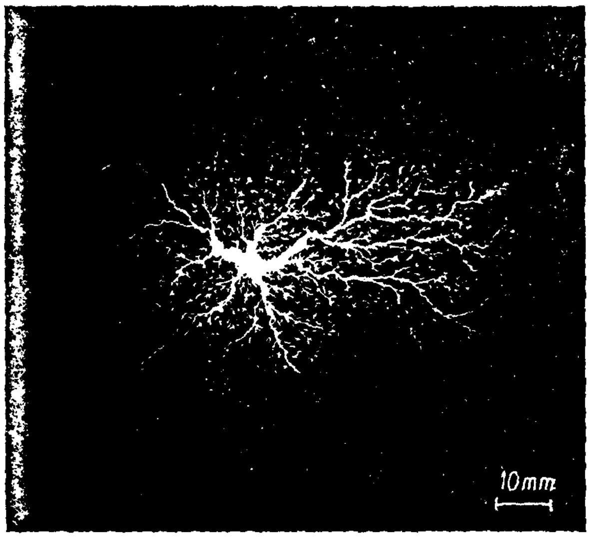


Figure 13
Current in transition from Leader to Reversing Leader
($\hat{u}_1$=125 kV; c = 0.9pF/cm^2
50/5000; pos.glide pole)

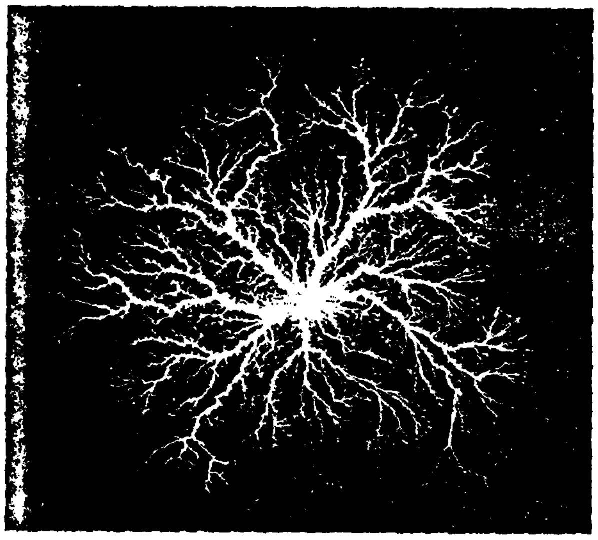
rably and thereby its conductivity. The heads of individual leader tracks are not any further participating in this process as in free oil space. While in free oil space the necessary charge carriers,as for instance with negative counter electrode, are made available by the γ-effect, the large current density (1-10 A/mm^2) in glide processes is achieved by means of high capacitive currents (Eq.(1)) which close over the leader tracks. The observed phenomenon is therefore here also identified as "reversing leader".

The investigations in free oil space as well as those in glide configurations indicate that the development of the discharge configuration in oil is predominantly determined by the current density in the tracks. The negative peak pulse currents are considerably larger than the positive (Fig.6), and the negative discharge configuration shows leafy branchings (Figs.11 and 12). If the positive peak pulse currents reach similar high values, such ramifications also occur here (Fig.14). An analysis of the space-time behaviour of reversing leaders [4] showed without doubt that the thickening and leafy branching of the tracks occur directly during the process and not, as assumed by MULLER [11], only tenths of a second after the voltage decay through "reactive discharges".

For negative glide poles, the reversing leaders are cha-

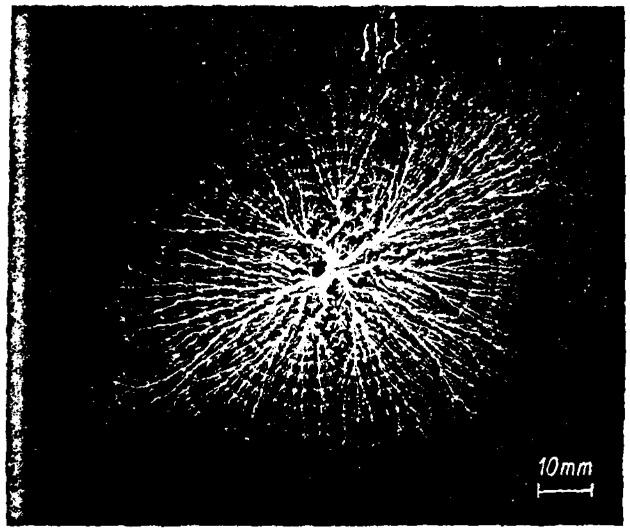


a) $\hat{u}_A = 45$ kV; 1/3500

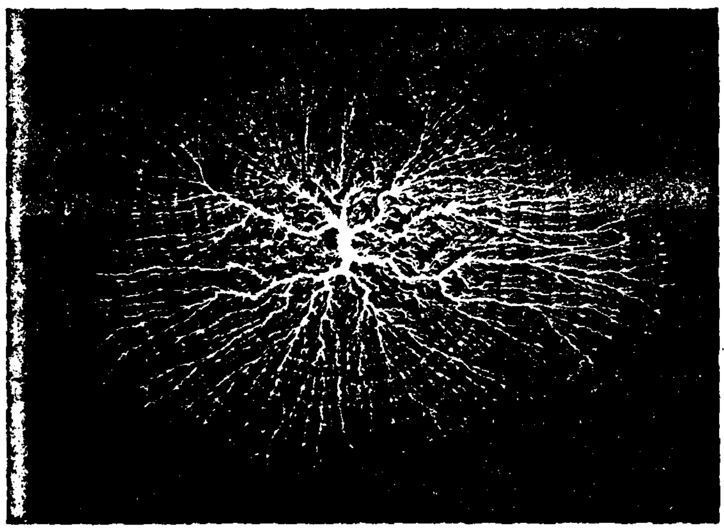


b) $\hat{u}_A = 55$ kV; 80/3500

Figure 14. Leader and Reversing Leader for positive glide pole
(c = 8.0 pF/cm^2)



a) $\hat{u}_A = 45$ kV; 1/3500



b) $\hat{u}_A = 55$ kV; 1/3500

Figure 15. Leader and Reversing Leader for negative glide pole
($c = 8.0$ pF/cm^2)

racterized in the glide configurations by particularly thick tracks (Fig.15). In the center of the discharge configuration exist many ramifications and branchings, which are considerably enlarged by the reversing leaders (Fig.15b).While the center of the negative discharge configuration is formed by reversing leaders, at the boundary always leaders are growing there first. Near concentric rings surrounding the glide pole (Fig.15) indicate that the configuration expands by a discrete distance with each group pulse (back step mechanism)(Fig.4).

With positive as well as negative glide pole, the occurrence of reversing leaders does not characterize a new discharge mechanism. Opposite to the leader, the degree of ionization in the tracks is increased considerably so that the longitudinal gradient is further reduced (see section 4). At the same time, the erosive effect on the solid material boundary is increased. The characteristic transformation of the discharge configuration, as well as the considerably increased currents and pulse loads and secondary importance of leader heads for the process, justify also for glide discharges the complementary definition of "reversing" to the "leader" concept.

4. Flashover Voltage

The flashover voltage level in a glide configuration is solely determined by the growth advance of the leader - and thereby by the longitudinal gradient in the leader track. This longitudinal gradient was determined in free oil space at appr. 10 kV/cm [4]. The gradient depends - as also in air [7]- greatly on discharge current and pulse load,respectively. If it is assured in a glide configuration that reversing leaders do not yet occur, then the slope of the flashover voltage versus flashover distance characteristic coincides

with the longitudinal gradient of the leader (Fig.16). Since at the occurrence of reversing leaders, on account of the higher degree of ionization of the tracks, the leader longitudinal gradient diminishes below 10 kV/cm, the slope of the $\hat{u}_{\Lambda\ddot{u}}$ versus $\ddot{u}$ characteristic can also diminish below this value. However, it was not possible to measure such characteristics completely, as it was necessary to utilize thin glide plates on account of the required high specific surface capacitance, and they would be punctured as a rule rather than flashed across.

In order to assess the flashover behaviour of a glide configuration at differently shaped pulse voltages, the ranges of leaders are compared at constant peak voltages (Fig.17) The range is thereby defined as the distance between the head of the longest leader and the glide pole (Figs 8 and 11). At constant decay time and peak voltage, the leader range diminishes with increased rise time (Fig.17). The range is mainly determined by the first group pulse, which will be stronger as steeper the voltage rise, which means as shorter the rise time. This mechanism is especially effective, if the rise time is small in comparison with the pulse duration of the first leader group pulse, which is in the order of several ten to a hundred microseconds. The first leader starts possibly already at the voltage peak value and can - at long current pulse duration - already revert partially into the reversing leader. This is already the case in the example of figure 17 for pulse voltages 1/3500 and voltages $\hat{u}_{\Lambda} > 45$ kV (range $l > 45$ mm). The leader longitudinal gradient, which is even smaller than the quotient $\hat{u}_{\Lambda}/l$ diminishes then to a value below 10 kV/cm.

The first leader can not revert into a reversing leader, if the pulse voltage already diminishes during the growth of the first leaders on account of its short decay time (Fig.17;

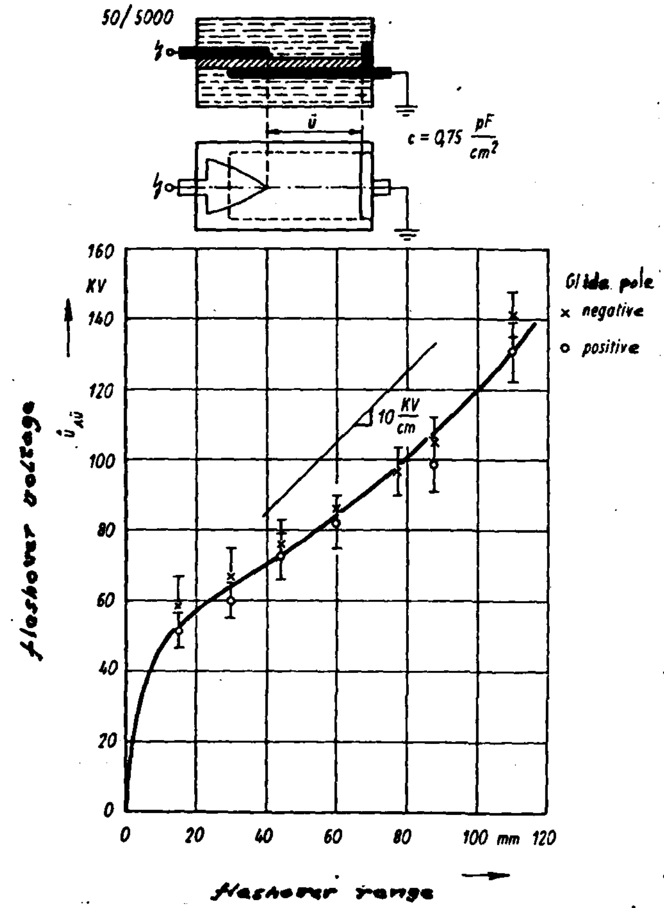


Figure 16.
Flashover Voltage
versus Flashover
Range

Pulse voltage 1.2/50). Also the occurrence of leaders of higher serial number becomes improbable.At short decay half times, the advance growth of the leader is hindered by the voltage reduction and the range remains small (Fig.17).

It can be deduced from the observations of flashover ranges in glide discharges that the flashover voltage at glide configurations diminishes with increased decay half times and diminishing rise times of the pulse voltages. A pronounced polarity effect can thereby not be expected (Fig.16).This behavior of the flashover voltage corresponds to that of the

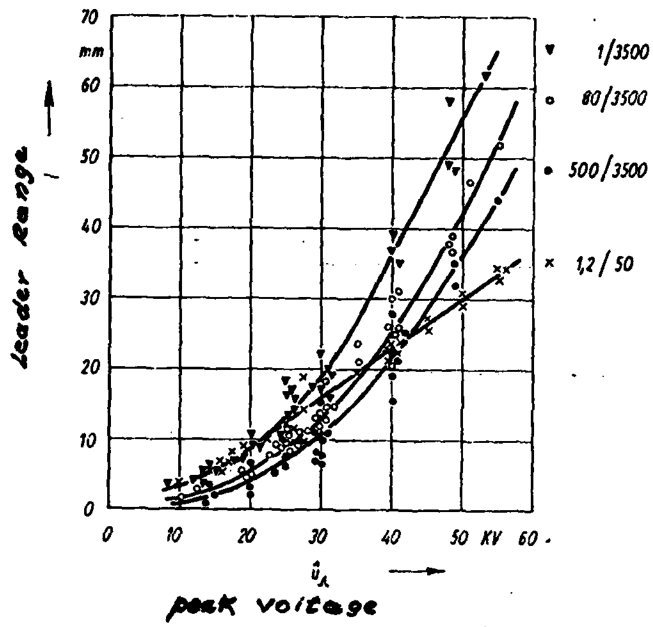


Figure 17.
Leader Range versus
Peak Voltage
for positive glide
pole
(c = 8 pF/cm^2)

penetration voltage in largely inhomogeneous free oil space, where the penetration process is also dependent on the growth advance of the leaders 9 .

5. Conclusions

The investigations again confirmed the already customary requirement, that for glide configurations under oil, leader discharges have to be avoided at operating voltages. The characteristic graphs, which resulted from measurements in a Toepler glide configuration point-to-plate with dependence on specific surface capacitance, can be considered as lowest values for leader initiating voltages at pulse voltages.

At low load stresses with pulse voltages - as would be the case when an oil filled high voltage instrument is tested - one can certainly assume that no damage occurs to the solid insulating material through leader discharges, for those solid insulating materials which are usually used in conjunc-

tion with transformer oil. However, if reversing leaders occur, erosive destruction must be expected. Since the occurrence of reversing leaders is more probable at switching transients than at impulse voltages of the same amplitude, an examination of an existing switch voltage (protection) circuitry may become the determining examination for oil filled high voltage instruments which contain glide configurations. It is recommended to investigate by means of a model configuration , whether at the test switch voltage reversing leaders can occur in the instrument, or not.

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